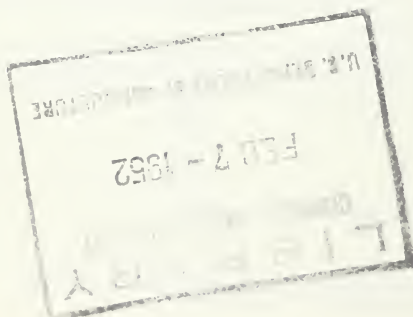


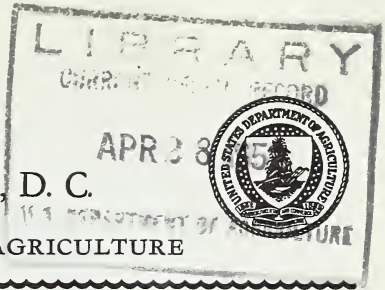
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Thermostabilization of Shell Eggs: Quality Retention in Storage

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SUMMARY AND CONCLUSIONS

The research here reported shows that the rate of deterioration of shell eggs can be retarded by heating the eggs to 130° to 136° F. in oil for 16 minutes, the best results being obtained at 134°. This process, known as thermostabilization, makes it possible to have more high-quality eggs in storage, after a given period, than the use of ordinary commercial methods, thus offering a substantial advantage in marketing. After 7½ months of storage the number of Grade A eggs remaining in the lots which had been thermostabilized averaged 84.0 percent, while the number in the lots that were oiled but not heated averaged 37.8 percent.

The cost per case for the thermostabilization operation is only slightly higher than that for the ordinary oiling operation.

Temperature readings during the study showed that in thermostabilizing eggs the rate of flow of oil over individual eggs was sufficient to effect rapid heat transference to the egg without lowering the temperature of the oil more than 1° F.

¹This report covers a part of the research program of the Poultry Branch directed toward the solution of problems of a technical nature encountered under commercial plant-operating conditions. The work was carried on under authority of the Research and Marketing Act of 1946.

Acknowledgment is made to the Henderson Egg Corp. and the Gordon Johnson Co. for material, facilities, and assistance in conducting the work, and to W. A. Nichols of the Gordon Johnson Co. for aid in obtaining certain temperature readings.

²Recently resigned from the Poultry Branch.

The surface temperature of the egg did not rise sharply during thermostabilization; it took about 10 minutes to reach maximum temperature. On the other hand, the internal egg temperature did not reach its maximum until approximately 4 minutes after the egg was removed from the heating medium.

For each degree Fahrenheit of rise in stabilizing temperature, from 130° F. (54.4° C.) to 136° F. (57.8° C.), there was a corresponding rise of 1.05° in the maximum internal temperature reached. For each 10° of difference in the initial internal temperature of the eggs there was a corresponding difference of 1.13° in the final internal temperature reached.

Eggs of approximately the same internal temperature showed approximately a 9° difference between the internal temperature after cooling for 16 minutes in still air and that attained in an air-blast tunnel at the same temperature.

Breakage of eggs in the machine was small for U. S. Grade A eggs thermostabilized between 130° F. (54.4° C.) and 136° F. (57.8° C.) for 16 minutes, but it rose sharply when a temperature of 144° F. (62.2° C.) was maintained for 8 minutes. Jumbo eggs showed marked breakage and day-old U. S. Grade AA eggs showed excessive breakage during treatment.

Shell eggs thermostabilized at 134° F. (56.7° C.) for 16 minutes showed better quality retention after 7½ months of cold storage than did those thermostabilized at 132° F. (55.6° C.) or 136° F. (57.8° C.). This confirmed previous research results on the storage of thermostabilized eggs. There was no significant difference in yolk index of U. S. Grade A eggs at any of the temperatures used, but a maximum albumen index was found for the 134° F. (56.7° C.) treatment.

It is concluded that a maximum retention of quality in shell eggs during storage can be obtained by thermostabilizing to a maximum internal temperature of approximately 122.3° F. (50.2° C.), and that this can be attained by heating eggs of an initial internal temperature of 60° F. (15.6° C.) in flowing oil for 16 minutes at 134° F. (56.7° C.). When the initial internal temperature varies from 60° F. (15.6° C.) the correct final internal temperature can be obtained by adjusting the oil temperature approximately 1.13° for each 10° difference in the initial internal temperature of the eggs.

INTRODUCTION

The process known as thermostabilization, developed at the University of Missouri by E. M. Funk, makes shell eggs resistant to normal deteriorative changes (1, 2, 3, 4, 5).³ Because of the increased retention of the quality of eggs thus treated, this process seems to offer certain physical and economic advantages in storing and marketing shell eggs. The application of the process to commercial operations is feasible and, aside from the somewhat higher initial cost for equipment, the cost of the operation, including the oil, is only slightly more than that of ordinary oiling. The authors of the publications cited proved that the best results with the method are obtained at temperatures in the range of 130° F. (54.4° C.) to 136° F. (57.8° C.),

³ Italic numbers in parentheses refer to Literature Cited, page 12.

and that the length of time that brings the best results from such treatment is from 15 to 16 minutes, at these temperatures.

As comparatively little information was available on the rates of heat transference in the heating and cooling of shell eggs, and as it is not always possible under commercial conditions to work with eggs of uniform temperature, it was believed desirable to study certain of these factors. Also, it was believed desirable to obtain further information on the retention of quality during the storage of eggs thermostabilized at different temperatures.

EXPERIMENTAL PROCEDURE

A custom-made egg-treating machine (4), employing as a heating medium a thin film of heated oil flowing over the surface of the shell, was used (fig. 1). Thermostabilization and shell oiling were accomplished in one operation by heating the eggs to the desired temperature with 50- to 60-viscosity oil, thermostatically held at a given temperature. To cool the eggs after treatment, a custom-made air-blast tunnel conveyor system was used. Funk (3) showed that cooling is necessary to prevent stuck yolks.

All temperature readings were made by the use of fine copper and constantan wires, fused at the end to form a thermocouple junction

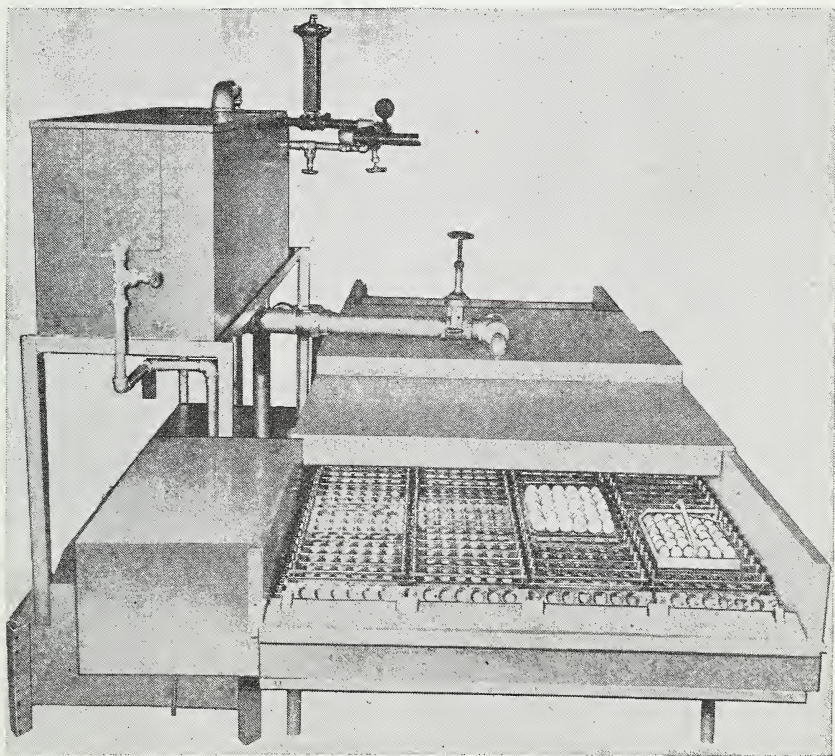


FIGURE 1.—Custom-made machine used for thermostabilizing eggs. The eggs, placed on a moving conveyor, were carried at constant speed through the heating area, where hot oil flowed over them.

and connected with a Leeds and Northrup electric potentiometer. Readings were made to the 0.01 millivolt and were converted to the equivalent temperatures by means of conversion tables. Air velocities were measured with an anemometer; relative humidities were determined by placing wet- and dry-bulb thermometers in the air stream of the tunnel cooler.

To insure uniform distribution of heated oil over the eggs a distributing device was placed above the eggs. The device consisted of a shallow pan with a series of small holes punched in it in such a pattern that each egg was under at least one stream of oil at all times as it moved through the machine. Thus, as the eggs were moved by the conveyor through the machine, they were continuously supplied with a thin film of constant temperature oil. To determine the heat loss and heat transference of this system and to record the temperatures at various points, a series of thermocouples was placed at strategic points and readings were made during actual operation.

The thermostabilizing machine was equipped with temperature controls which held the temperature of the oil constant within a 1° F. variation. The oil temperature readings were not taken from the continuous record chart; they were taken with thermocouples immersed in the oil at various points. Continuous temperature readings of the interior of shell eggs were made through thermocouples inserted in the center of the yolk.

One part of the study was designed to record various time and temperature relationships and the effect of the initial egg temperature on the final internal temperature attained. The other part was designed to determine the retention of the internal quality of shell eggs during extended storage.

U. S. Grade A, large eggs, weighing 2.13 to 2.23 ounces (60.5 to 63.5 grams) each, were used in the first part of the work; and eggs from commercial, wholesale lots in the second part. They were collected on farm routes, graded into wholesale lots, and hauled approximately 200 miles by truck to the point of study. Before treatment the eggs were recandled and full cases of sound, clean, U. S. Grade A, large eggs were made up. Two cases of day-old, 53-percent U. S. Grade AA eggs were the exception.

TEMPERATURE CHANGES DURING HEATING AND COOLING OF SHELL EGGS

To record temperature changes in the oil as it passed through the machine, one thermocouple was submerged in the oil in the distributing pan above the eggs and a second one was placed beneath an egg, where it was submerged in oil that had flowed over the surface of the egg in a thin film. To obtain the record a small metal trough, deep enough to hold sufficient oil to completely cover the thermocouple, was set just below the egg to catch the spent oil. Readings were taken at 1-minute intervals with the potentiometer.

The air temperature during the experiment varied from 72° F. (22.2° C.) to 74° F. (23.3° C.). The eggs were not shielded in any way and air passed freely through the machine. No cooling effect of the air on the oil was apparent. The temperature of the oil was recorded at 129° F. (53.9° C.) both at the beginning and the end of the run; it fluctuated approximately 1° during the run. The oil

collected after flowing over the egg showed no drop in temperature and the temperature was recorded as being within a fraction of a degree of that of the oil in the distribution pan. This was true even at the beginning of the run when the egg was cold. The total temperature drop of the oil, from the distributing pan through to the return to the oil-heating tank, was approximately 1°F .

Another run was made to determine the relationship between the oil temperature and the rate of heating of the shell surface and of the interior of the egg. One thermocouple was submerged in the oil in the distributing pan; another was fastened to the shell at the small end of the egg by means of a plastic adhesive; a third was placed in the center of the yolk through a small hole drilled in the air-cell end of the egg, the wires being held in place by plastic cement. The results of this run are shown in figure 2.

The average temperature of the oil was $135.1 \pm 0.3^{\circ}\text{F}$. (57.3°C .) during the run. The initial temperature of the egg was 80.6°F . (27°C .). Although the temperature of the shell surface increased rapidly, it did not reach the maximum of 133.7°F . (56.5°C .) until the egg had been under the oil for 10 minutes. As the egg left the oil bath at the end of 16 minutes the surface temperature remained constant until the hot oil had drained away; then the temperature began to drop rapidly, leveling off as the temperature of the interior of the egg was reached: it dropped rapidly as the egg was placed in the air-blast cooler. The air used in this tunnel cooler had a temperature

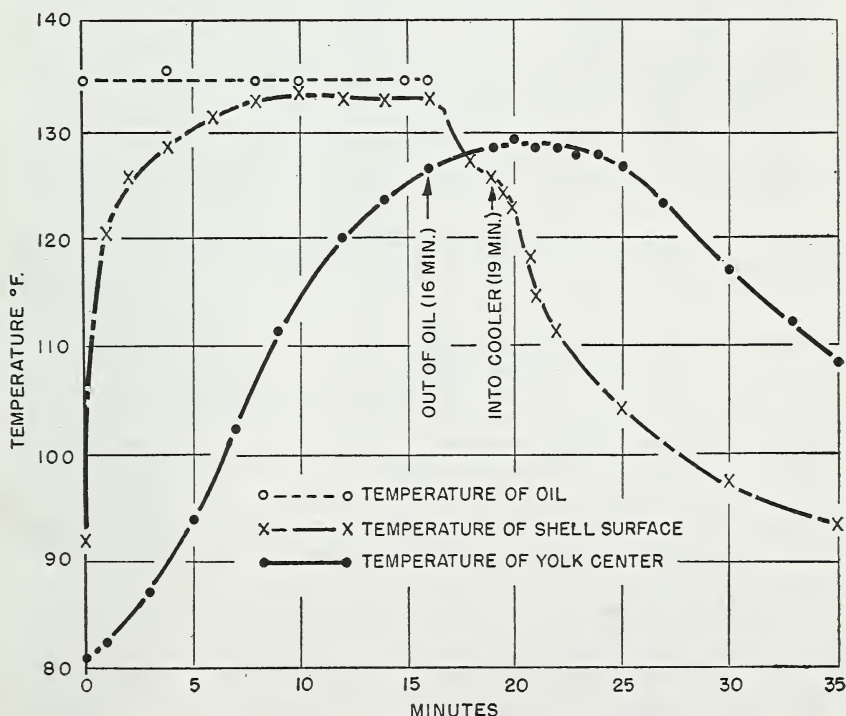


FIGURE 2.—Rates of heating and cooling of surface and interior of shell egg during thermostabilization.

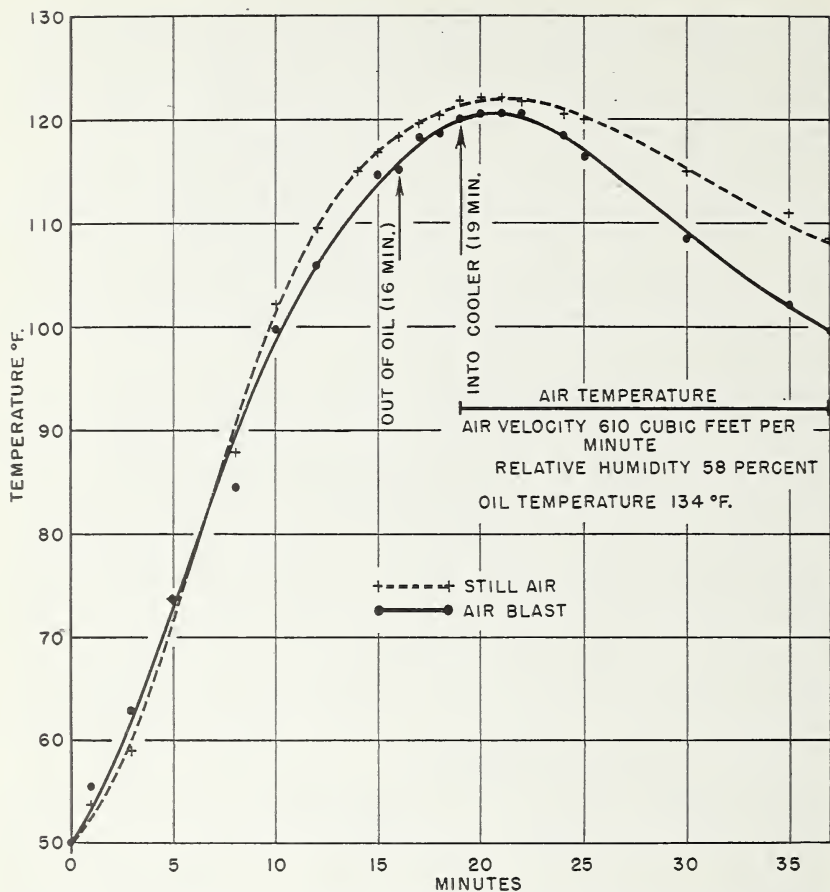


FIGURE 3.—Temperature changes of eggs during thermostabilization and rates of cooling in air blast, compared with cooling in still air, after thermostabilization.

of 80.6° F. (27° C.); the relative humidity was 54 percent; the air velocity was 610 cubic feet per minute.

The temperature at the center of the egg increased slowly; after 16 minutes, when the egg was removed from the oil bath, it had reached 126.5° F. (52.5° C.). However, it continued to rise for 2 minutes to attain a maximum of 128.3° F. (53.5° C.). At this point the egg was placed in the tunnel cooler. The temperature then began to drop rapidly. After 15 minutes of air-blast cooling the temperature in the center of the egg was 107.6° F. (42° C.); that of the shell surface was 93° F. (33.9° C.).

The effectiveness of the air-blast tunnel cooling of the eggs is shown in figure 3. Two eggs of equal size and of the same initial temperature were equipped with thermocouples in the centers of the yolks. The eggs were then passed through the machine and temperature readings were taken at 1-minute intervals. The temperature of the oil was

134° F. (56.7° C.); the initial interior temperature of the eggs, 53.6° F. (12° C.). After heating for 16 minutes under a film of oil, one egg had attained a temperature of 115° F. (46.1° C.) and the other 118.4° F. (48° C.). This difference was probably due to failure to place the thermocouples in exactly the same position in the two eggs. The maximum temperatures reached were 120.4° F. (49° C.) and 122° F. (50° C.), respectively, 4 minutes after removal from the heating medium.

One egg was placed on a piece of soft cardboard, to prevent contact with a wooden surface that might act as a cooling agent, and allowed to cool in still air. The other egg was placed in the air-blast tunnel cooler with an air velocity of 610 cubic feet per minute, an air temperature of 87.8° F. (31° C.), and a relative humidity of 58 percent. At the end of 16 minutes of cooling the egg in the air-blast cooler had an internal temperature that was 9° lower than that of the egg cooled in still air. The air was at "summer heat" temperature and no attempt at air cooling was made.

The results on cooling eggs of different temperatures in the tunnel at various air temperatures were not conclusive. Air temperatures varied from 72.5° F. (22.5° C.) to 91.4° F. (33° C.); yet the difference in rate of cooling was small and the results variable. The over-all pattern, however, indicated that the refrigeration of air for the cooling of treated eggs would be impractical as the results obtained would not be commensurate with the added expense.

Readings were recorded for each temperature used for the thermostabilization of eggs. Thermocouples were inserted in the centers of a series of eggs and readings were taken during stabilization at oil temperatures of 130° F. (54.4° C.), 134° F. (56.7° C.), and 136° F. (57.8° C.). The results are presented in figure 4. The eggs were of approximately the same internal temperature at the start; the rise in temperature during heating brought the eggs to the maximum internal temperatures in approximately 17 minutes. The maximum temperatures reached for the three foregoing stabilizing temperatures were 118.4° F. (48° C.), 120.4° F. (49° C.), and 124.7° F. (51.5° C.), respectively. The difference between the high and low oil temperatures used was 6°; the difference between the maximum internal temperatures of the eggs treated at those temperatures was 6.3°, or a 1.05° increase in final internal temperature for each 1° increase in oil temperature. After the heated eggs were placed in the air-blast cooler, they cooled at slightly different rates, but roughly in the same proportion as their rates of heating.

Under commercial conditions it is not always possible to have eggs at a specified temperature before processing. To determine the final differences that could be expected with eggs of different starting temperatures, thermocouples were inserted in a series of eggs and each cooled to a different internal temperature before placing it in the thermostabilizing machine. The oil temperature used was constant at 136° F. (57.8° C.) and temperature readings were made at 1-minute intervals. The results are shown in figure 5.

With initial temperatures as low as 49° F. (9.4° C.) and as high as 80.6° F. (27° C.), or a spread of 31.6°, the temperatures attained in the various eggs at the 16-minute interval were only 4.3° apart. At the 19-minute interval, when the eggs were transferred to the air-blast

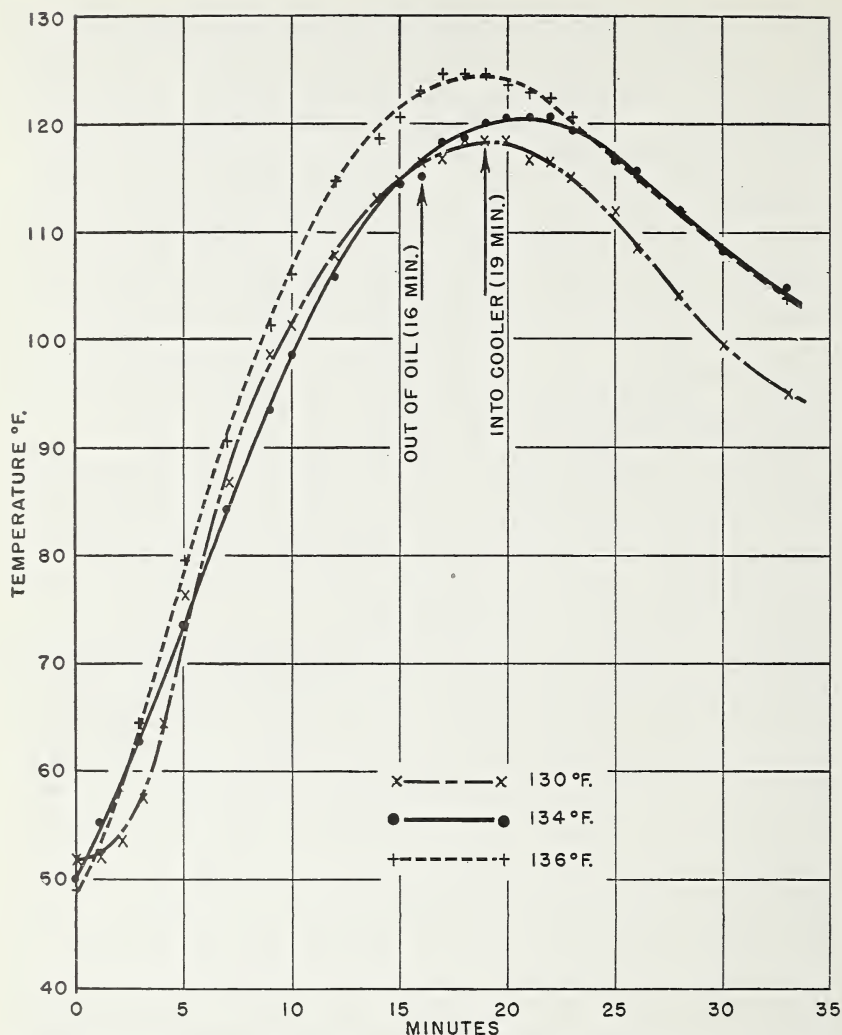


FIGURE 4.—Temperature changes in interior of shell eggs resulting from thermo-stabilization under various temperatures.

cooler, the temperature difference was only 3.6°. Thus, for a difference of 10° in initial temperature there was a final temperature difference of 1.13°. These results indicate that the 16-minute interval of heating has the advantage of equalizing the internal temperature of shell eggs (fig. 5), and that if eggs to be stabilized have an internal temperature of 50° F. (10° C.), instead of 60° F. (15.6° C.), owing to weather conditions or removal from a cooler, the required final internal temperature can be reached by increasing the stabilizing temperature by 1.1°. On the other hand, if the weather is warm and the eggs are received with an internal temperature of 75° F. (23.9° C.), the oil temperature should be adjusted downward by 1.7°, in order to attain the correct final temperature.

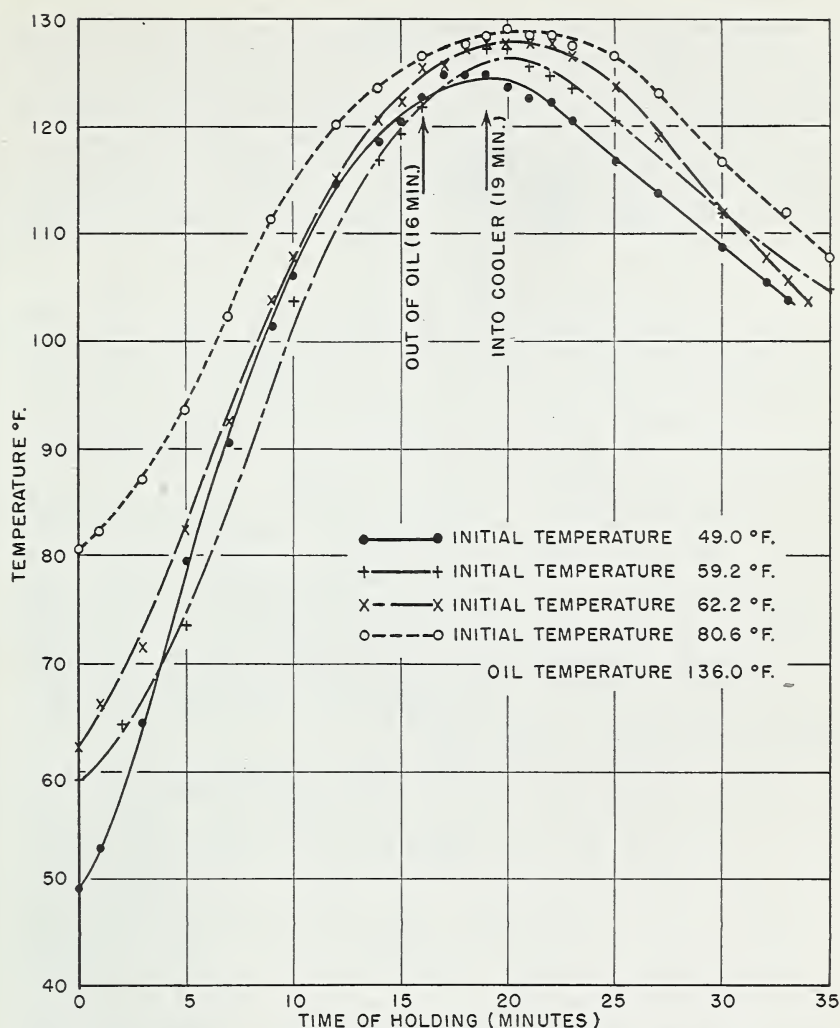


FIGURE 5.—Changes in internal temperatures of shell eggs of varying initial temperatures thermostabilized at 136° F.

BREAKAGE

During the heating process the internal expansion of the liquid caused certain eggs to check; these were easily detected by the wide dark line of the crack. These eggs contracted on cooling and the check became almost invisible except before the candling light. The record kept of the number of machine checks found in 10 cases of eggs at each of the processing temperatures shows:

Temperature of stabilization:

	Number of machine-checked eggs per 10 cases
130° F. (54.4° C.)	4
132° F. (55.6° C.)	3
134° F. (56.7° C.)	3
136° F. (57.8° C.)	5
144° F. (62.2° C.)	17

A high percentage of jumbo-sized eggs when treated became checked, regardless of the temperature of stabilization, probably because the air cell was not big enough to provide space for the liquid expansion. That this was true was indicated also when two cases of day-old, 53-percent U. S. Grade AA eggs were stabilized. The record showed 18 machine checks out of 576 eggs stabilized at 130° F. (54.4° C.) and 134° F. (56.7° C.). This is equivalent to a count of 112 checked eggs for 10 cases, compared with the 3 or 4 eggs listed as heated at the same temperatures.

STORAGE

In previous research (4) differences in the temperature of stabilization for the 16-minute interval resulted in slightly different keeping quality during storage. Keeping quality increased as the temperature of stabilization was increased until approximately 134° F. (56.7° C.) was reached, and keeping quality declined with further increases in temperature. To verify these findings, a new series of thermostabilized eggs was processed and placed in storage.

The eggs were candled into full cases of U. S. Grade A, large eggs, and were thermostabilized at 130° F. (54.4° C.), 132° F. (55.6° C.), 134° F. (56.7° C.), and 136° F. (57.8° C.). One lot was thermostabilized at 144° F. (62.2° C.), a heating time of 8 minutes being used instead of the 16-minute interval on the other lots. The purpose of this test was to see if the capacity of the machine could be increased by a change in the time-temperature ratio. One lot of oil-dipped eggs was included as a control. These eggs were dipped for ½ minute in oil of the type used for the thermostabilizing and held at a constant temperature of 100° F. (37.8° C.).

The internal temperature of the eggs was approximately 60° F. (15.6° C.) at the time of thermostabilization. The eggs were randomized by making up cases of single flats from each of several cases. As soon as the treated eggs were removed from the machine they were transferred to the air-blast tunnel cooler, which had an air velocity of 610 cubic feet per minute and was equipped with a continuously moving wire belt. The rate of travel was such that the eggs passed through the cooler in 16 minutes. The size and the time interval were chosen to synchronize with the rate of travel in the thermostabilizing machine. Because the weather was warm, large pieces of ice were placed in the inlet air duct to lower the temperature. The temperature of the air in the blast cooler ranged from 78° F. to 81° F. (25.6° to 27.2° C.).

After being cooled to an internal temperature of approximately 100° F. (37.8° C.), the eggs were cased, the lids were nailed on, and the cases were delivered to the refrigerated warehouse for storage. The storage rooms were held at 30° F. \pm 1° F. (-1.1° C.).

After 7½ months in storage the eggs were removed from the warehouse and graded by candling. Table 1 shows the results.

At the time the eggs were placed in storage each case contained 360 U. S. Grade A eggs and the average number remaining as U. S. Grade A was used as the index of quality retention by the various treatments.

Only 37.8 percent of the oil-treated eggs were still Grade A after 7½ months of storage, as compared with 78.9 to 85.0 percent of the thermostabilized eggs. The highest quality retention was obtained at a thermostabilization temperature of 134° F. (56.7° C.)

TABLE 1.—*Quality retention of shell eggs, by grades and yolk and albumen indexes, stored 7½ months after thermostabilization or oil treatment*

Treatment	Cases	Average number of eggs per grade in each treatment after 7½ months of storage									
		U. S. Grade A	U. S. Grade B	U. S. Grade C	Loss	Lowest and high- est Grade A's per case	Percent- age Grade A	Yolk index		Albumen index	
								Can- dled ¹	Broken out ²	Can- dled ¹	Broken out ²
Thermostabilization at:	Number	Number	Number	Number	Number	Number	Percent	0. 396	0. 397	0. 0522	0. 0557
130° F., 16 minutes-----	7	300	55	3	2	277-315	83. 3	. 391	. 398	. 0536	. 0580
132° F., 16 minutes-----	6	302	54	2	2	284-323	83. 9	. 387	. 392	. 0599	. 0618
134° F., 16 minutes-----	7	306	50	2	2	282-331	85. 0	. 402	. 394	. 0563	. 0579
136° F., 16 minutes-----	7	302	54	2	2	261-327	83. 9	. 394	. 398	. 0594	. 0601
144° F., 8 minutes-----	5	284	68	3	3	270-302	78. 9	³ . 418	³ . 414	. 0462	. 0510
Oiled only-----	7	136	216	6	2	98-171	37. 8				

¹ Eggs judged U. S. Grade A by candling.² Eggs judged U. S. Grade A broken out.³ Swollen yolks.

and a slightly less retention of quality at temperatures both above and below that figure. The spread between the high and low numbers of Grade A eggs in the cases shows that the distribution was very uniform. These results confirmed the previous results, which showed that the maximum quality retention during storage was obtained with the 134° F. (56.7° C.) temperature.

The eggs stabilized at 144° F. (62.2° C.) showed a lower percentage of Grade A eggs, but a much higher percentage than the eggs that were oiled only.

The yolk and albumen indexes, obtained from broken-out eggs after 7½ months of storage, were determined by dividing the height of the yolk or the albumen by the corresponding average diameters. They were arranged both on the assumption that the candled grade of the egg was U. S. Grade A and that the broken-out grade of the egg was Grade A. Very little difference was found when the two indexes were arranged in this manner, indicating that the candling was accurate.

The yolk index shows no significant change with the increase of the thermostabilization temperature. There was a slight increase in the albumen index with an increase in temperature, the maximum being reached with a temperature of 134° F. (56.7° C.), and a slight decrease with a temperature of 136° F. (57.8° C.). The albumen index of the 144° F. (62.2° C.) series was almost the same as that of the 134° F. (56.7° C.) series.

In this storage study maximum quality retention was obtained by thermostabilizing eggs, with an initial internal temperature of approximately 60° F. (15.6° C.), for 16 minutes at 134° F. (56.7° C.). From the information presented in figures 4 and 5 it is calculated that the final internal temperature reached under those conditions was approximately 122.3° F. (50.2° C.); also, that when these exact conditions do not obtain, the correct internal temperature can be reached by adjusting the temperature of the oil to compensate for the difference in initial egg temperature. Thus, if the initial internal temperature were 50° F. (10° C.) the oil temperature would be adjusted upward by 1.13° F., or by a thermostat setting of 135.1° F. (57.2° C.) on the thermostabilizing machine; or, if the initial temperature were 75° F. (29.9° C.), the thermostat setting would be made at 132.3° F. (55.7° C.).

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